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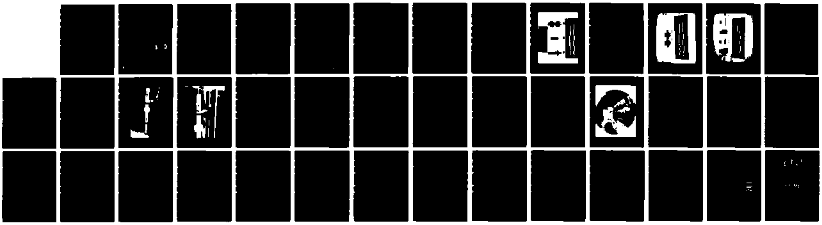

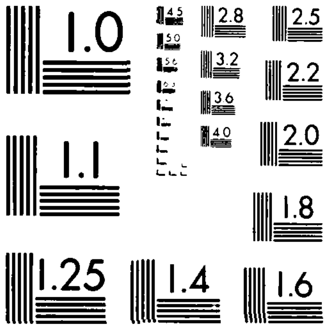

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MEMORANDUM REPORT BRL-MR-3444

AN APPARATUS FOR OBTAINING CONTROLLED SHOT-START PRESSURE IN A GUN TUBE

Anthony F. Baran

May 1985

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US ARMY BALLISTIC RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND

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An apparatus for obtaining a desired shot-start pressure has been designed, fabricated and successfully tested. This "Shot-Start Projectile Apparatus" is composed of metallic and nonmetallic parts. It is fabricated to a set of drawing specifications which do not change even though the projectile is used in a gun tube which erodes from continued firing. Design characteristics, method of assembly and installation, calibration and test data are presented and discussed.

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

I. INTRODUCTION

A worn gun tube produces many variations in interior and exterior ballistic performance and makes the determination of performance parameters unreliable. To accelerate and launch a projectile properly from a gun tube, a rotating band or obturator is placed around the projectile near its base to make the projectile fit tightly in the bore, thereby preventing the escape of propellant gases. Gun tubes erode from repeated firings by the motion of high temperature gases and residues generated from burning propellant, by chemical action, and by friction between the projectile and the bore. As the gun tube erodes, the initial pressure needed to accelerate the projectile is reduced and hot gases escape around the projectile causing increased tube wear, decreased projectile velocity, and decreased launch stability. To reduce the variability in these parameters, several methods can be used to try to reproduce the ballistics of a good gun tube.

One practice to compensate for an eroded gun tube is to machine or mold a rotating band or obturator of larger diameter than the eroded cross section of the barrel at the critical seat position. This would require either a slightly larger band or obturator for each firing or several made to the same oversize diameter. However, the first one would be difficult to seat and have to be rammed whereas the last would tend to be easy to seat.

A second practice is to transport the gun tube to a machine shop where either part of the chamber end of the gun tube would be removed and a new chamber would be machined in the tube to eliminate the worn area, thereby making the gun tube shorter, or boring out the chamber in order to replace the removed material with a sleeve having the original chamber dimensions.

These practices are time-consuming and produce additional problems for the ballistician and test personnel. In order to be able to continue testing without having to perform either of the above mentioned practices, a projectile was designed that would produce consistent shot-start pressures.

II. REQUIREMENT

During the barrel design phase of the Traveling Charge Program[1] it was decided to fabricate a ballistic tube in such a manner as not to be constrained by a specific length of a propellant chamber. Therefore the tube was fabricated as a 40-mm smoothbore from breech to muzzle, as shown in Figure 1. This design allowed the projectile to be positioned at specific distances from the breech face, thereby allowing the ballistician to have control of the chamber volume, propellant charge weight, charge-to-mass ratio and propellant density.

The projectiles that were initially used (labelled "1" and "2" shown in Figure 2) were forced into the bore to the proper distance for a specific chamber volume, the band obturator being slightly larger than 40-mm. The area in which the projectiles were seated became eroded after about twenty firings and the projectiles fit loosely into the tube. As a consequence, good

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1 *I.W. May, A.F. Baran, P.G. Baer, P.S. Gough, "The Traveling Charge Effect," Memorandum Report ARBRL-MR-03034, July 1980. (AD B052 135L)*

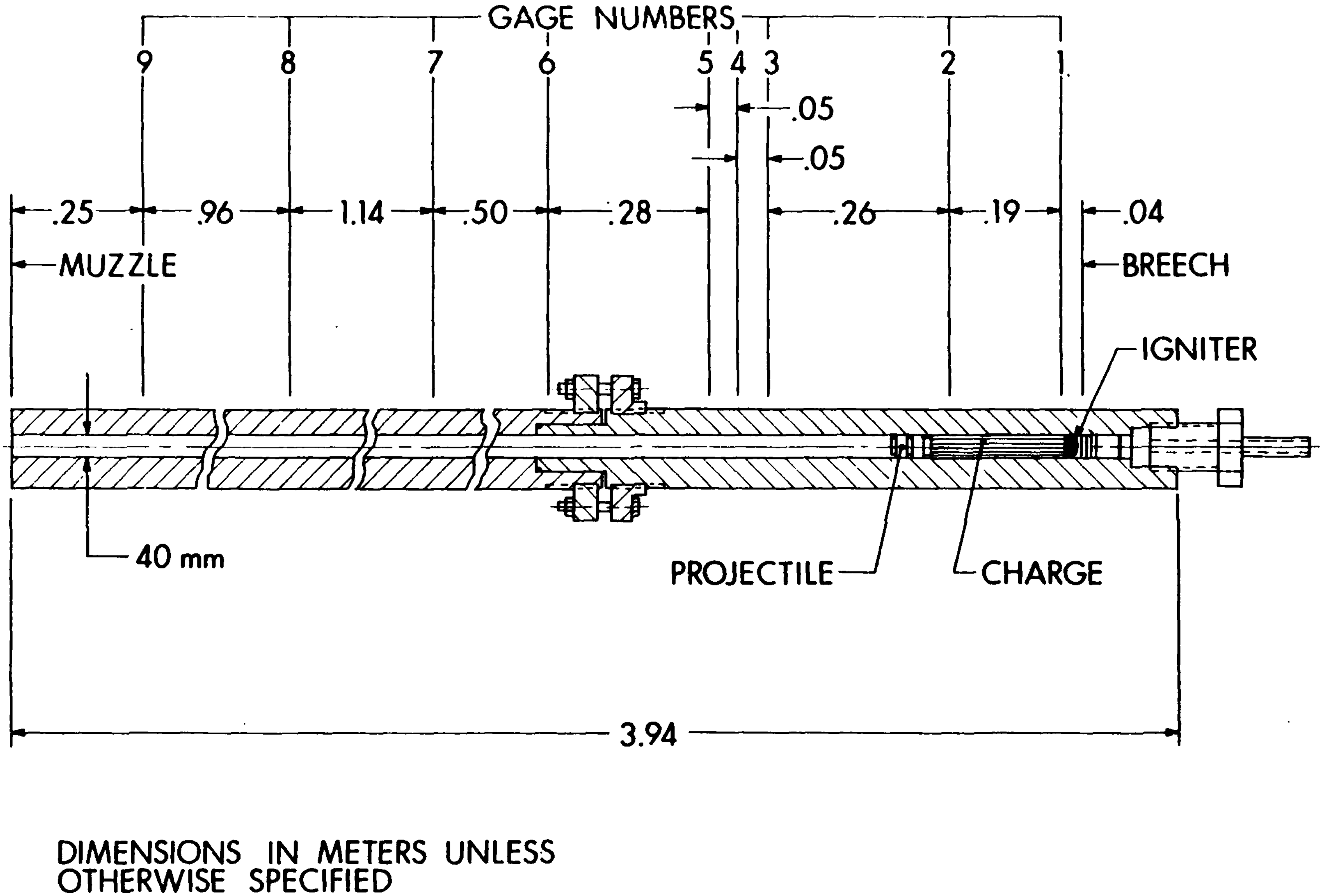

Figure 1. Sketch of the 40-mm Smoothbore Ballistic Tube

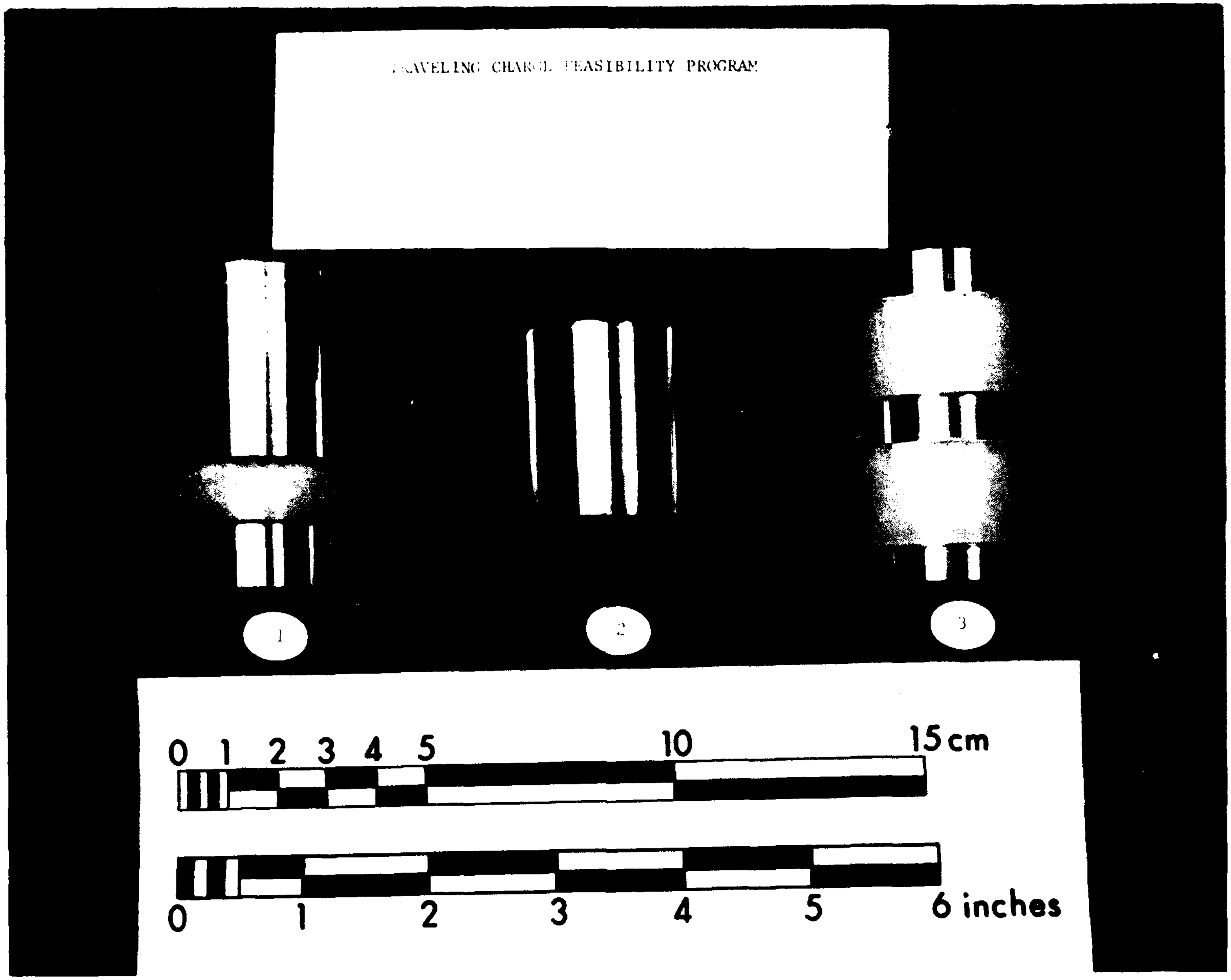

Figure 2. Fabricated Shot-Start Projectile

ignition of the propellant bed could not be obtained. A substantial and consistent shot-start pressure was needed in order to obtain proper ignition of the propellant bed for comparative results. Just making the rotating band larger, to accommodate the wear, would not provide similar shot-start conditions.

III. DESIGN

A means of obtaining a consistent shot-start pressure was required. One method was to attach a known diameter rod to the base of the projectile and to the breech face with the propellant around the rod. Knowing the properties of the rod, a pressure at which the projectile would apply a force that would shear the rod could be determined analytically and could easily be verified experimentally. This would work for loose propellant. However, with solid cylinders of consolidated propellant, an additional problem of providing a hole through the center of the cylinder would have to be considered.

Another method was to place a rod of a specific diameter through the barrel in front of the projectile that would shear at a specific load. This would preclude a specific set of chamber volumes instead of a variable chamber. Special plugs would be required for each set of chambers to prevent gas leakage and a clamping device would be needed to secure the shear rod. This method had potential hazards of damaging the projectile and/or the bore if the rod did not shear properly.

A method was required to produce repeatable shot-start pressures, while the bore surface was becoming larger after each shot because of erosion, and to cause minimal damage to the projectile and the bore surface in the process. Another major constraint was that the projectile had to weigh 160 grams.

An idea to meet these needs was conceived and called the "Shot-Start Projectile Apparatus," detailed in Appendix A. The apparatus consists of a special projectile. The first design of this projectile is shown assembled in Figure 2 (Labelled "3") and in Figure 3 and disassembled in Figure 4. The metal parts (1, 3 and 5) were made of aluminum and the bands (2 and 4) were made of low density polyethylene. These five parts include an alignment nut (1), front band (2), alignment sleeve (3), rear band (4) and a torque bolt (5). The alignment nut is considered the front of the projectile. The outside diameter of the bands is slightly larger than the other three parts of the apparatus.

The front and rear bands are identical. The front end of the band has the outside diameter chamfered with an included angle of approximately 60 degrees. The alignment sleeve is symmetrical. The head of the torque bolt is considered the rear of the projectile.

The following procedure is used to assemble the shot-start projectile: 1) the rear band is placed on the shaft of the torque bolt with the outside chamfer facing the threads of the shaft when positioned against the torque bolt head, 2) the alignment sleeve is then placed on the shaft of the torque bolt followed by the front band, 3) the front band is placed on the shaft to be symmetrical with the rear band, and 4) the alignment nut is then tightened

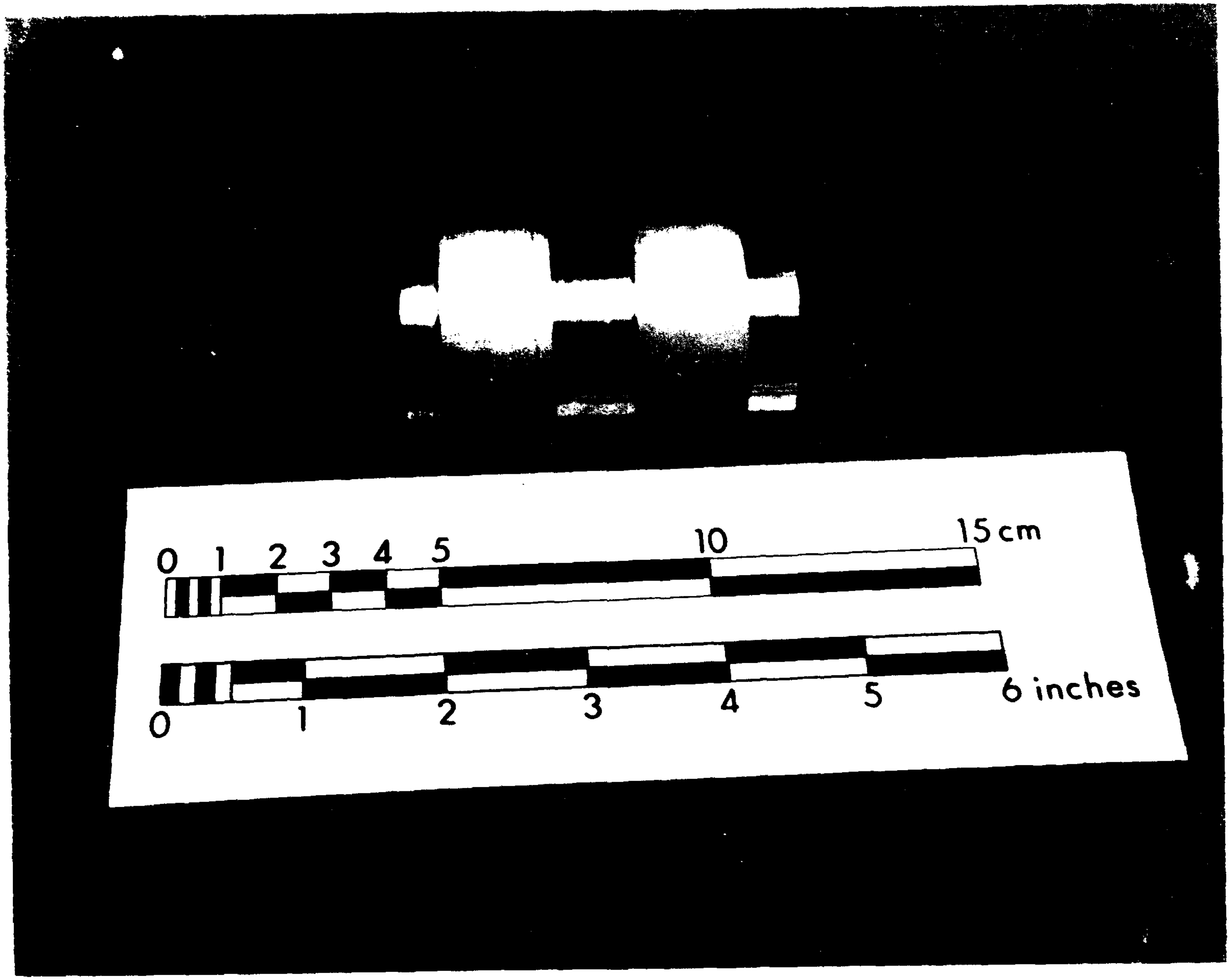

Figure 3. Shot-Start Projectile Apparatus, Assembled

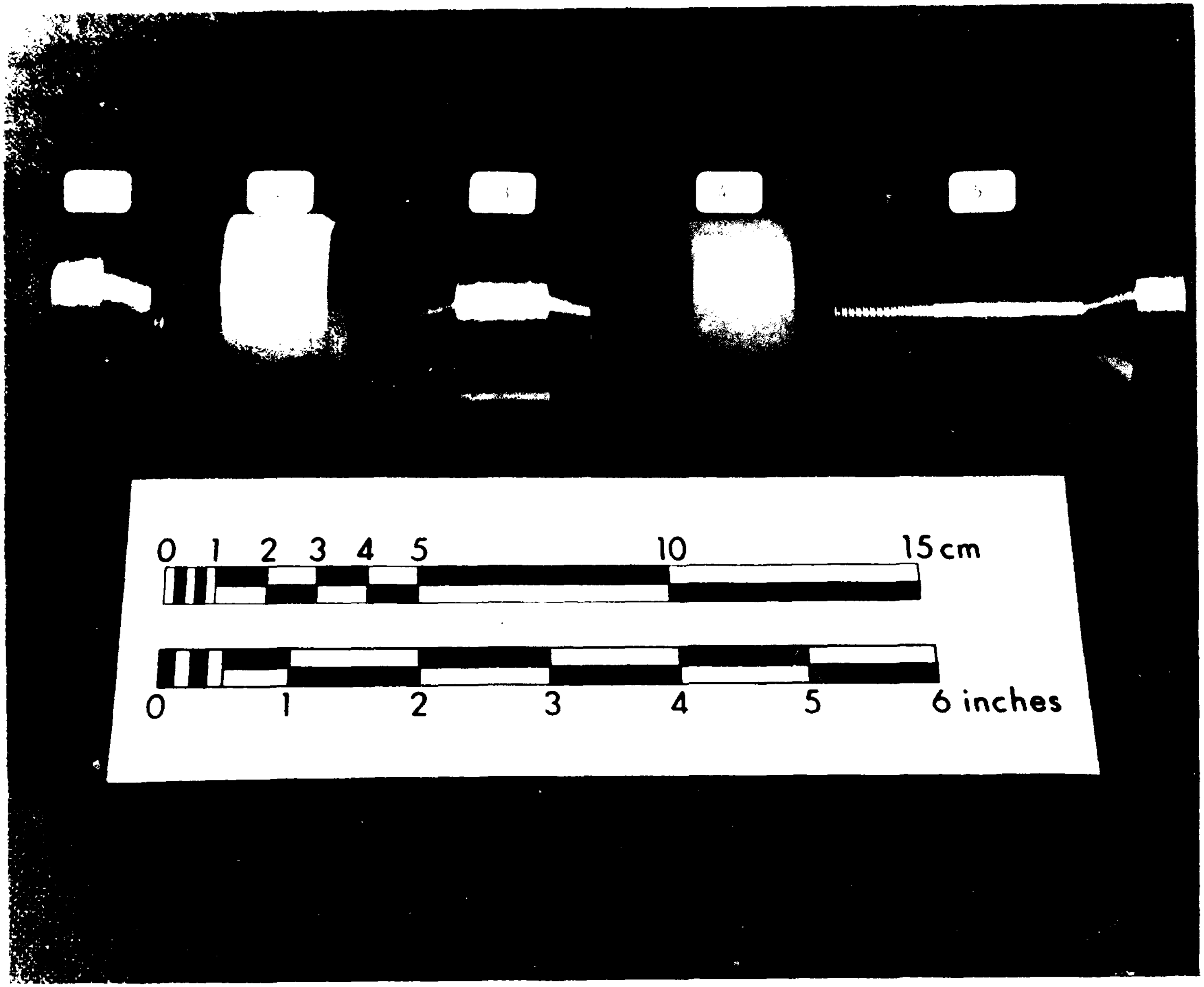

Figure 4. Shot-Start Pr[illegible] Apparatus, Disassembled

by hand on the torque bolt shaft, with the conical surface facing the front band, until all five components are finger tight.

The projectile is inserted in the tube to the projectile seat position. The torque bolt is rotated clockwise while holding the alignment nut from rotating. The rear conical surfaces of the bands have a slightly smaller included angle than the mating parts where localized contact occurs. As the alignment and torque bolt are tightened, a force is applied circumferentially to the bands at the point of interference between the bands and the mating parts that force the bands outward against the tube wall. The amount of torque applied to the torque bolt determines the normal force (N) with which the front and rear bands exert against the tube wall. On the ignition of the propelling charge, the projectile resists the driving force by virtue of static friction between the bands and the tube wall. The magnitude of this force, f, directed rearwards parallel to the tube axis, is given by

$$f \leqslant \mu N \quad ,$$

where μ is the coefficient of static friction.

In actual operation the charge is placed into the chamber and the breech closed. As ignition occurs, the flame from the igniter initiates burning throughout the main propellant charge that provides sufficient pressure to assure its good ignition before the shot starts to move. The front and rear bands provide obturation to prevent hot propellant gases from leaking in front of the projectile.

The alignment nut, part 1, is a retaining nut, used to position the front band and secure the assembled apparatus. The flat end contains four small diameter holes 90 degrees apart that are the same radial distance from the center line of the nut to accept a four pronged spanner used to tighten the apparatus. The opposite end has an included conical angle of approximately 90 degrees used to align the front band and force the band radially against the gun tube wall.

The front band, part 2, is a band/obturator. The position of the 60 degree included chamfer on the outside diameter is the front. The internal front conical angle of 90 degrees mates with the conical angle of the alignment nut. The internal rear conical angle of approximately 84 degrees does not mate with the conical angle of the alignment sleeve. Therefore, as the assembly is tightened, more band surface area is forced against the tube wall increasing the normal force.

The alignment sleeve, part 3, is a symmetrical spacer used to transmit equal force against both the front and rear bands as the assembly is tightened. The included angles of both ends are approximately 90 degrees.

The rear band, part 4, is identical to the front band and is positioned with the outside chamfer angle facing the alignment nut. The internal front conical angle is the same as the conical angle of the alignment sleeve. The internal rear conical angle of approximately 84 degrees does not mate with the conical angle of the torque bolt. Thereby as the assembly is tightened, more band surface area is forced against the tube wall increasing the normal force.

United States Patent [19]

Baran

[11] **4,307,666**

[45] **Dec. 29, 1981**

[54] **SHOT START PROJECTILE APPARATUS**

[75] Inventor: **Anthony F. Baran**, Fallston, Md.

[73] Assignee: **The United States of America as represented by the Secretary of the Army**, Washington, D.C.

[21] Appl. No.: **99,280**

[22] Filed: **Dec. 3, 1979**

[51] **Int. Cl.**³ **F42B 31/00**

[52] **U.S. Cl.** **102/525**; 102/501

[58] **Field of Search** 102/92.1-92.7, 102/93, 94, 91, 92, 501, 520, 524, 525

[56] **References Cited**

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704406	3/1941	Fed. Rep. of Germany	102/93

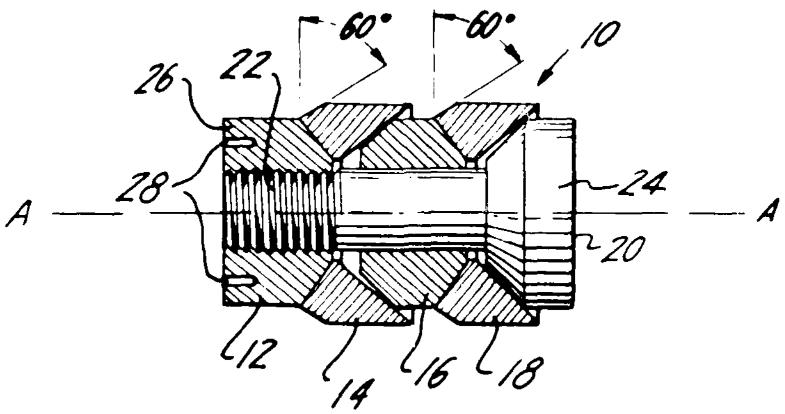
Primary Examiner—Harold D. Tudor

Attorney, Agent, or Firm—Nathan Edelberg; Robert P. Gibson; Max Yarmovsky

[57] **ABSTRACT**

The present invention discloses a shot-start projectile apparatus for a worn gun tube. The apparatus can be fitted to a projectile as an auxilliary obturator or can be designed to the proper weight and used as the projectile. The apparatus comprises a torque bolt, a rear band, an alignment sleeve, a front band and an alignment nut. The front and rear bands are identical and they are made of metallic or non-metallic material. The remaining components of the apparatus are made of metal. The front and rear bands provide obturation to prevent hot propellant gases from leaking in front of the projectile.

4 Claims, 8 Drawing Figures



APPENDIX A

UNITED STATES PATENT #4,307,666
SHOT START PROJECTILE APPARATUS

from rotating until the friction force was sufficient to prevent rotation between the components themselves and with the bore surface.

VII. CONCLUSIONS

A means was required to insure proper ignition of the main propellant charge in a worn gun tube. The shot-start projectile apparatus was designed to fulfill this requirement. This projectile was fabricated to a set of drawing specifications which do not change even though the gun tube continues to erode from continual firing. Therefore, a gun tube that ordinarily would be unserviceable due to wear can still be useful with such an apparatus. This projectile is easily positioned and secured at the desired projectile seat. Some of the advantages of the use of this type of projectile are:

1. The desired resistive force necessary for proper ignition and burning of specific propellants can be selected.

2. The projectile can be positioned in a wear region to provide good obturation.

3. The projectile could be used in a smoothbore or rifled tube.

4. The projectile uses nonmetallic bands which reduce gun tube wear.

5. Use of this projectile can extend the life of a gun tube by a considerable number of rounds.

6. The feasibility of this 40-mm shot-start projectile has been demonstrated and its use has provided reproducibility in obtaining consistent shot-start pressures.

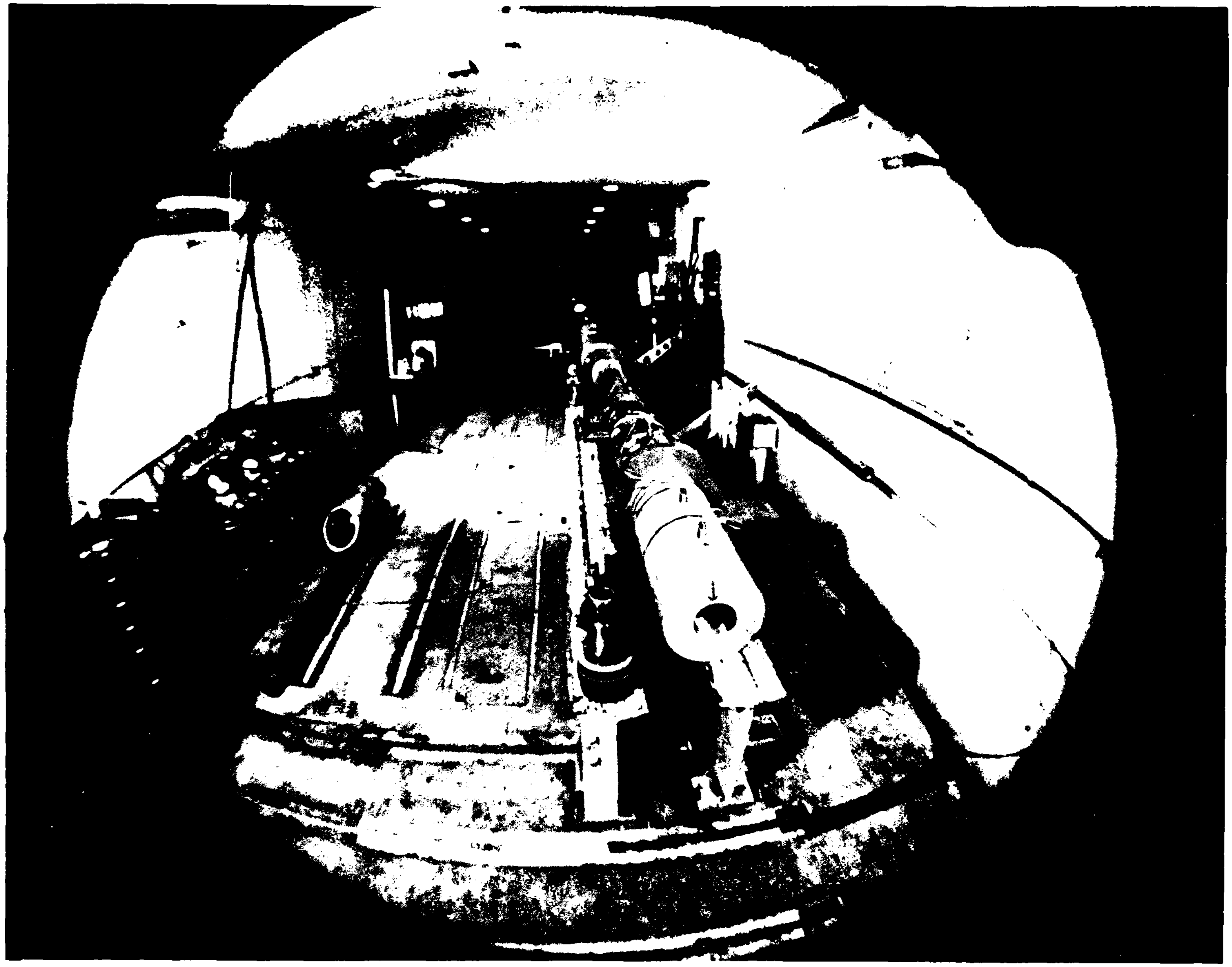


Figure 13. High Pressure, 6.1 meter long 40-mm Ballistic Tube

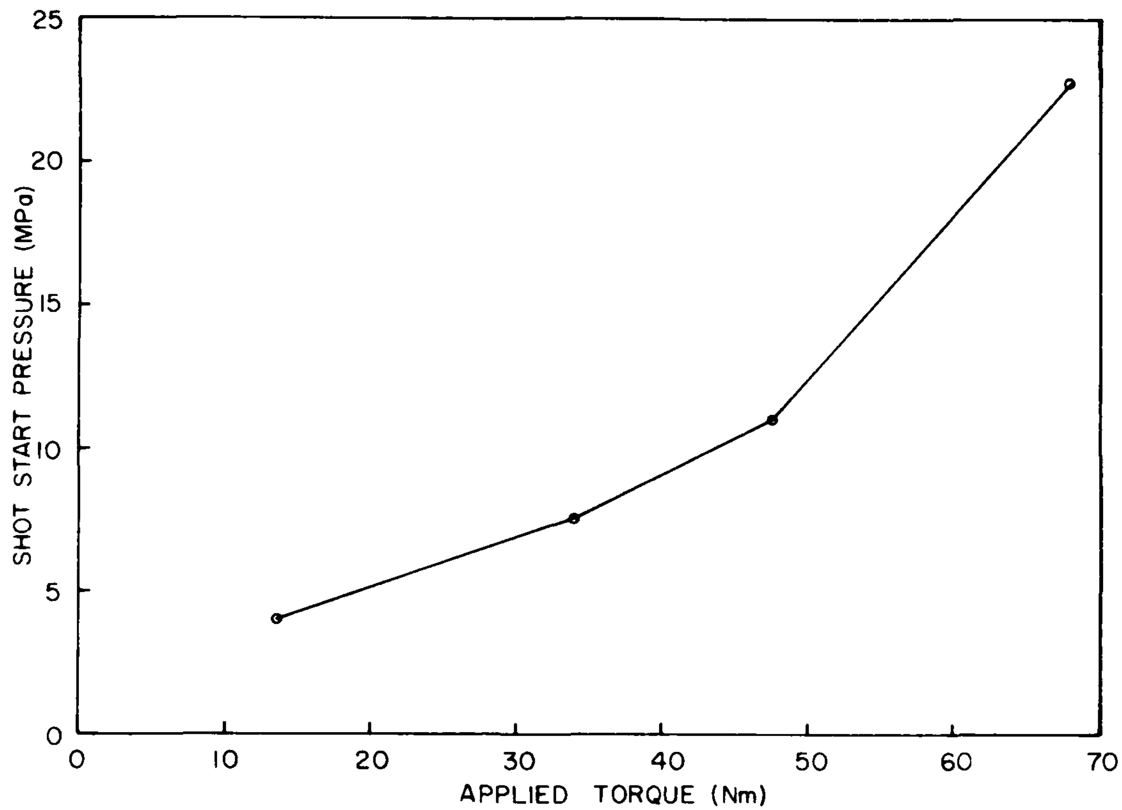


Figure 12. Measured Shot-Start Pressure vs Applied Torque Setting

frequency and breech pressure vs time of each round are presented in Figures 8 and 10. The output of the breech pressure gage and the gage where the base of the projectile is positioned for each round are plotted in Figures 9 and 11. The measured pressure at the base of the projectile at start of projectile motion for round 54 is 22.8 MPa (3.3 kpsi) and for round 56 is 11 MPa (1.65 kpsi). The data correlation was performed in two steps because of the manner in which the data were stored in the computer disc.

Normally, at the same point in time, the breech pressure is higher and has a faster rise time than the base pressure. In these tests the igniter was placed between the propellant charge and the base of the projectile. As can be observed and was expected this setup initially produced a higher base pressure than a breech pressure.

A plot of shot-start pressure vs applied torque is presented in Figure 12. To understand how these data were determined, refer to Figure 10. A deviation in the 10 GHz signal from its baseline indicates when the projectile has started to move. A vertical line was drawn at this point to intersect the breech gage output in order to determine the breech pressure at this time. A vertical line is drawn on Figure 11 at the same point in the time scale. Where this line crosses the output signal of the gage positioned at the base of the projectile determines the shot-start pressure. The breech pressure gage is also plotted as a position check.

The small sample of data does not show any direct correlation between the static calibration and the dynamic results as related to the shot-start pressure. The static calibration was conducted to determine if a linear relationship did exist between the applied torque, which produced an axial outward force, and a statically applied load on the base of the projectile. This was the case as was shown earlier in Figure 5.

VI. DISCUSSION

The shot-start projectile was designed to restrain the projectile from moving until the ignition train had successfully ignited the main propellant charge. Several design changes including material changes occurred throughout the test program.

To reduce weight the alignment sleeve material was changed from aluminum to Nylon 6/6. The front and rear bands were fabricated from Nylon 6/6 and low density polyethylene. The Nylon 6/6 was a better bore rider than the polyethylene, however, the polyethylene was more consistent in shot-start reproducibility at specific torque settings.

The initial method of positioning a projectile in the ballistic tube, Figures 1 and 6, required a long extension rod to hold the alignment nut from rotating until the friction force was sufficient to restrain the components from slipping on one another and the bands from slipping on the bore surface. Since a 6.1 meter ballistic tube, Figure 13, was to be used, a new method was needed to hold the alignment plug from rotating. To resolve this problem a 3.2 millimeter hole was drilled through the center of the torque bolt. The alignment nut was drilled and tapped with a 3 millimeter left hand fine thread. In this way one was able to position and set the torque from the breech end of the ballistic tube by using a rod to retain the alignment nut

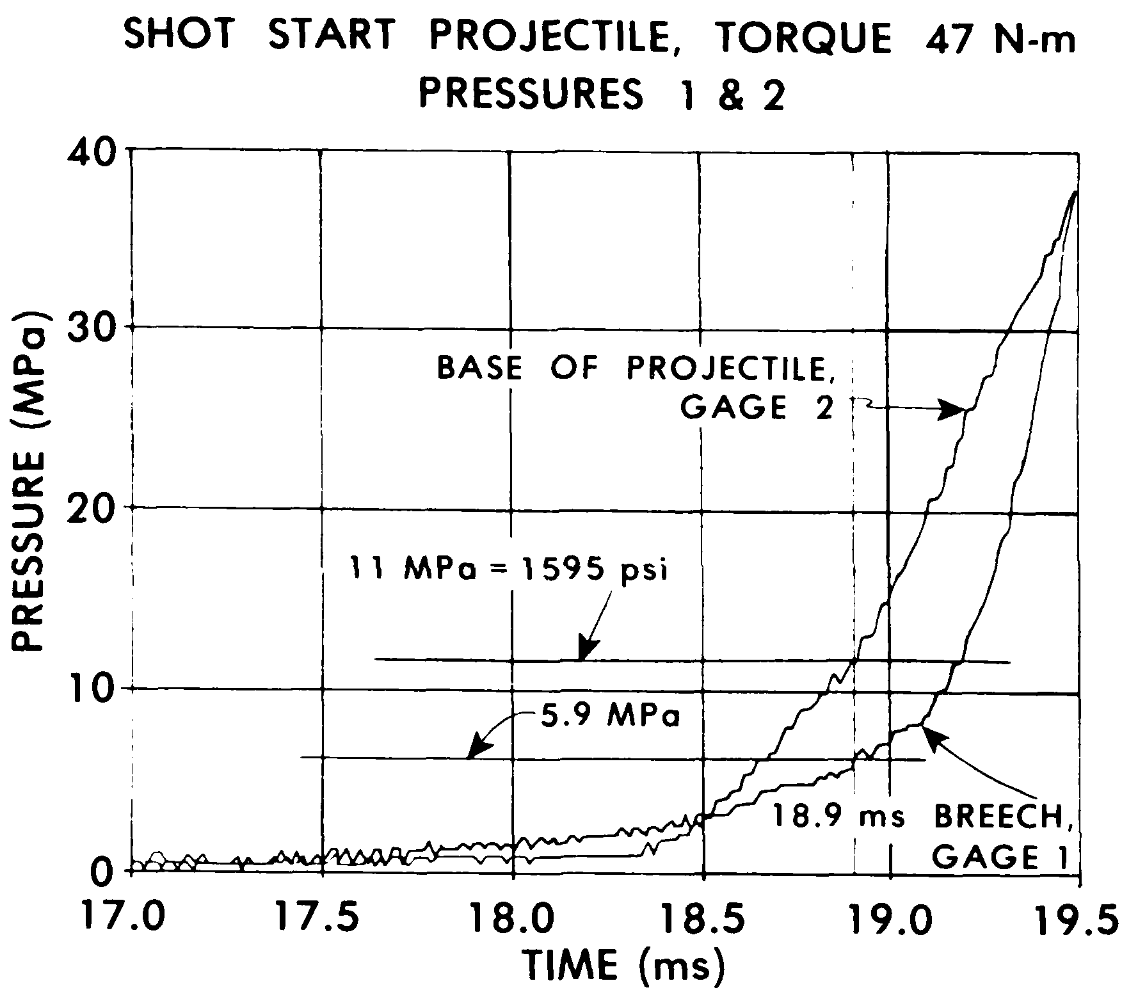


Figure 11. Round 56: Breech and Projectile Base Pressure vs Time

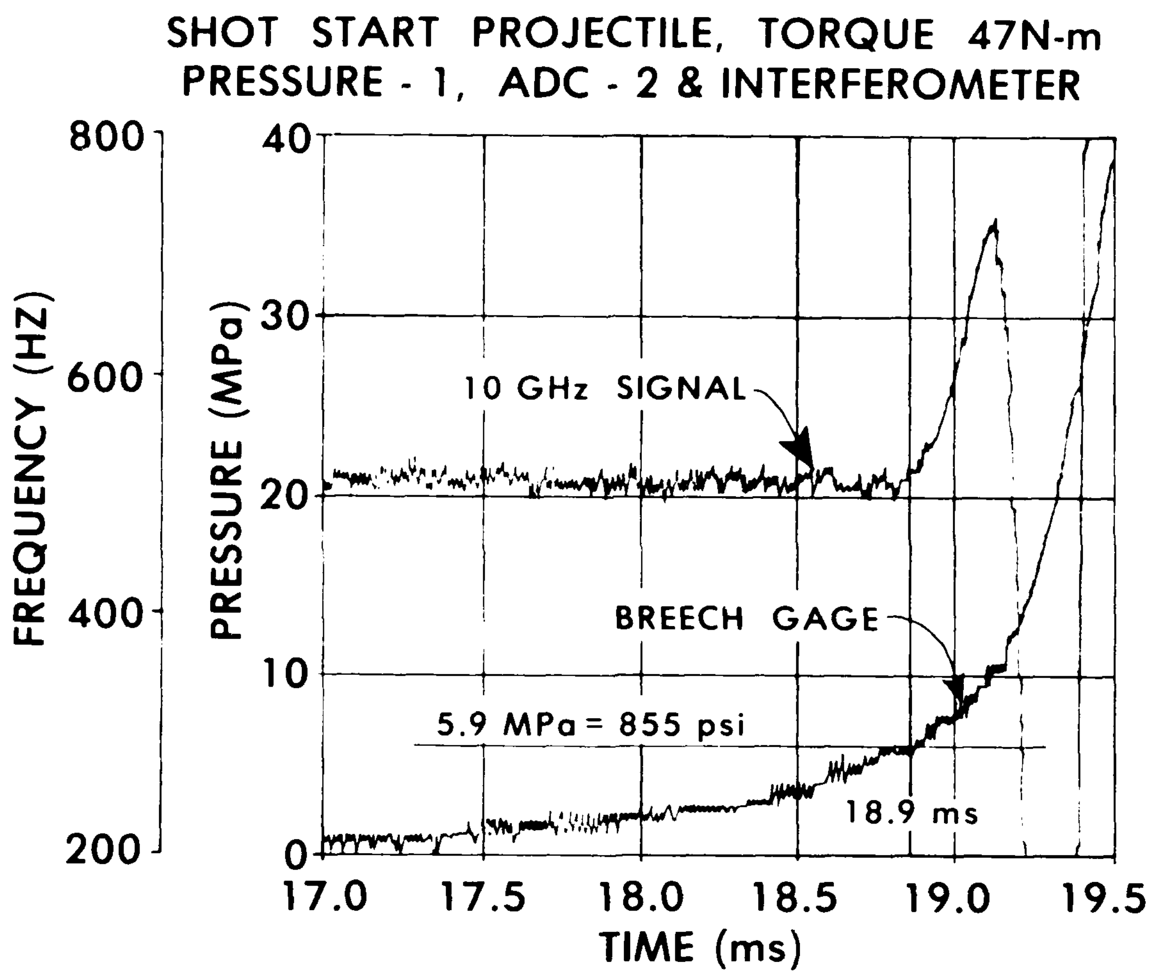


Figure 10. Round 56: Interferometer Frequency and Breech Pressure vs Time

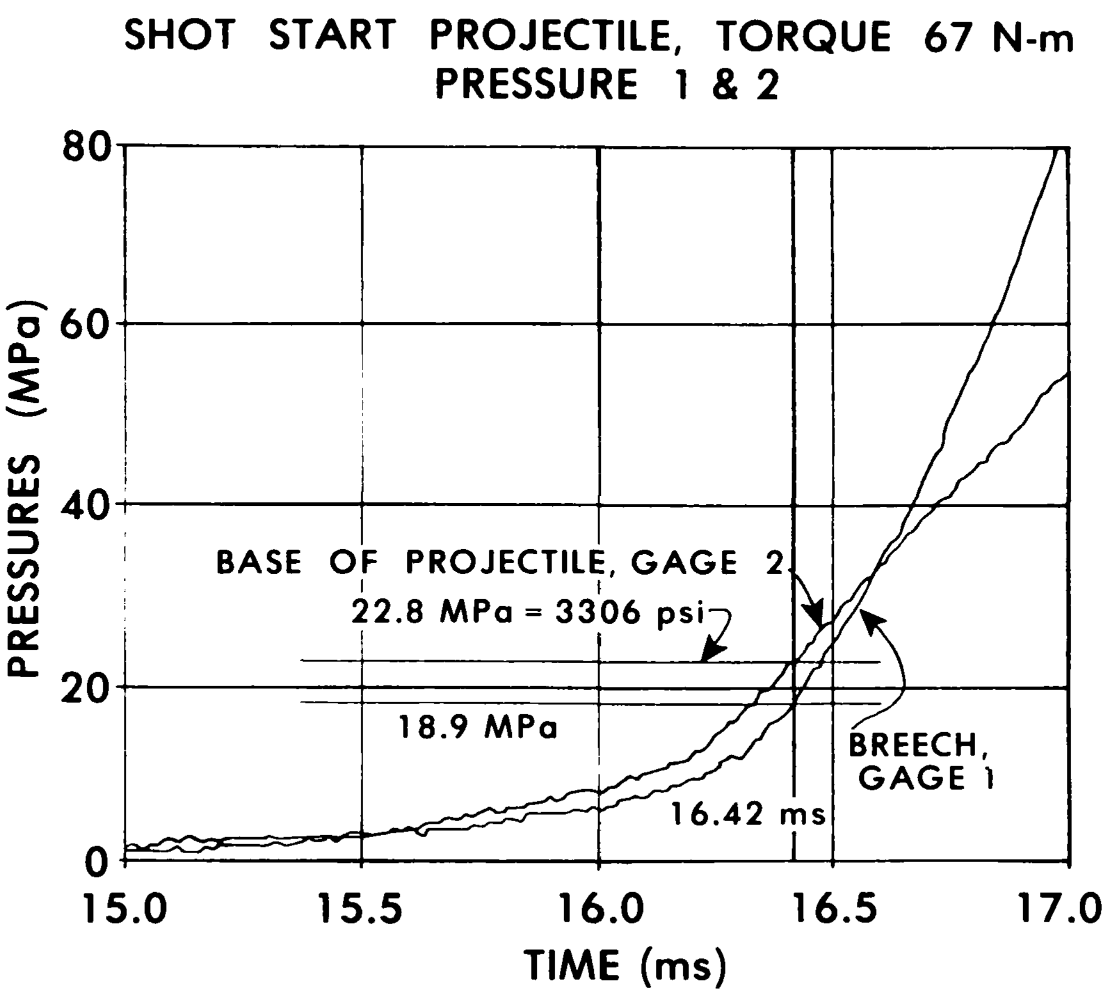


Figure 9. Round 54: Breech and Projectile Base Pressure vs Time

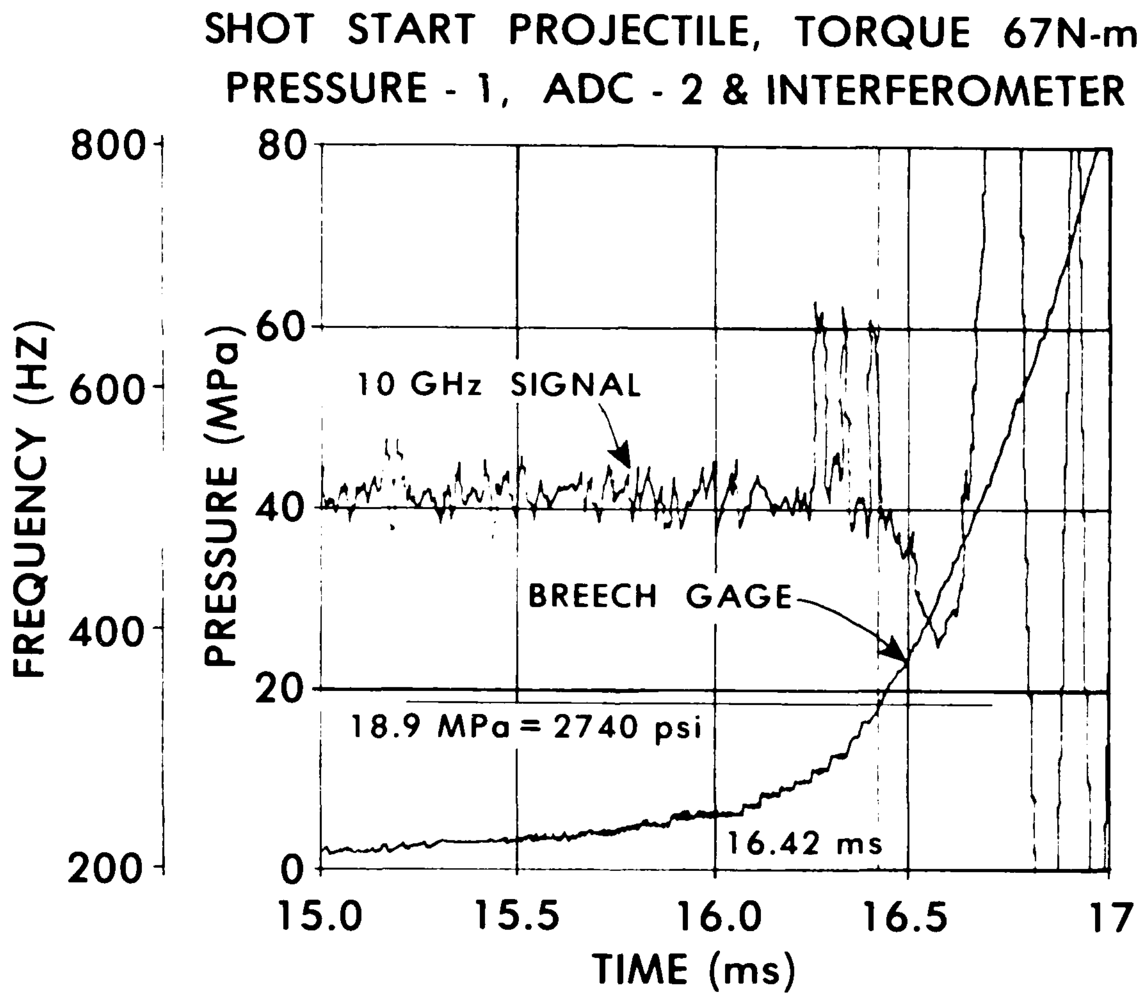


Figure 8. Round 54: Interferometer Frequency and Breech Pressure vs Time

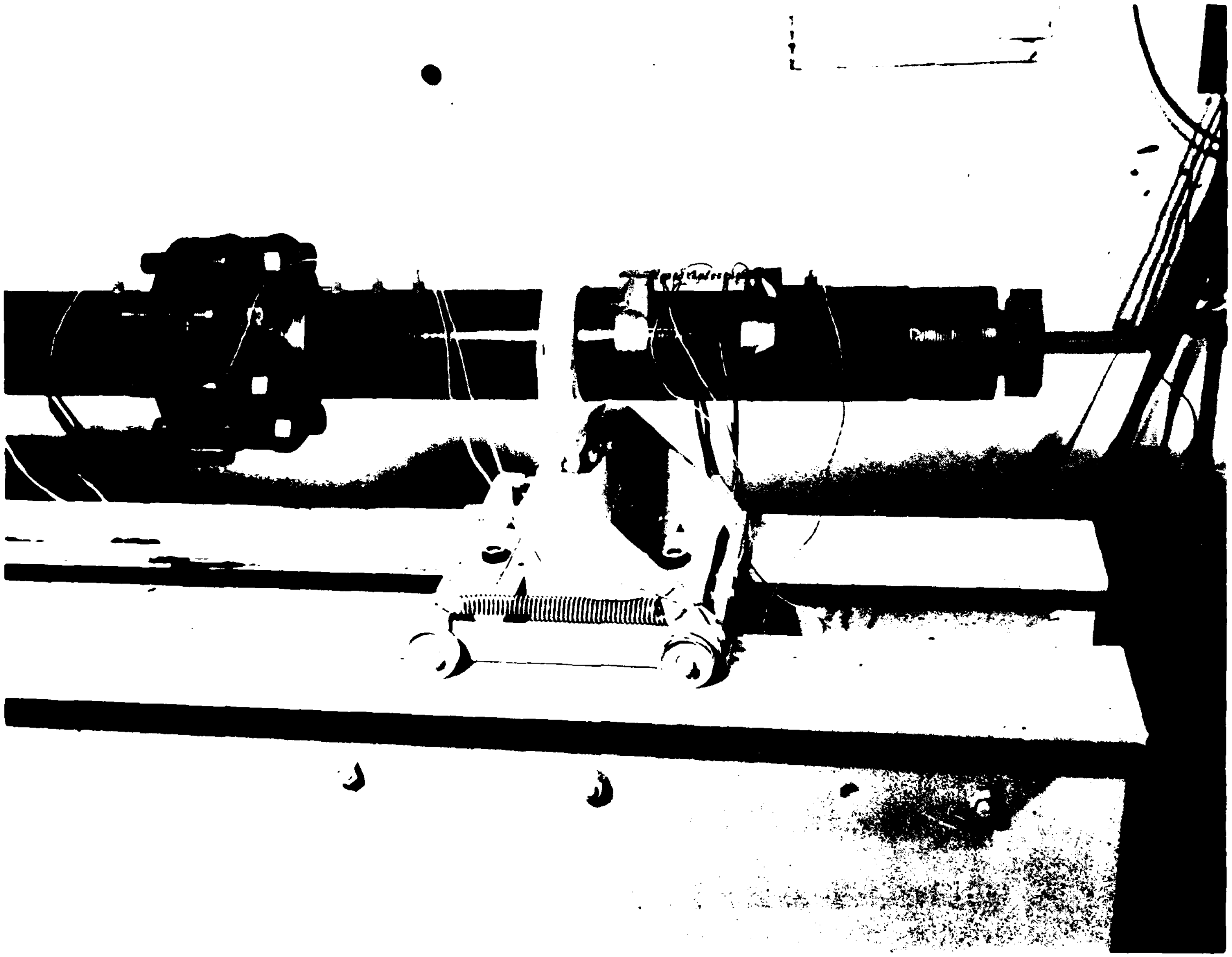


Figure 7. 40-mm Ballistic Tube, Chamber Section

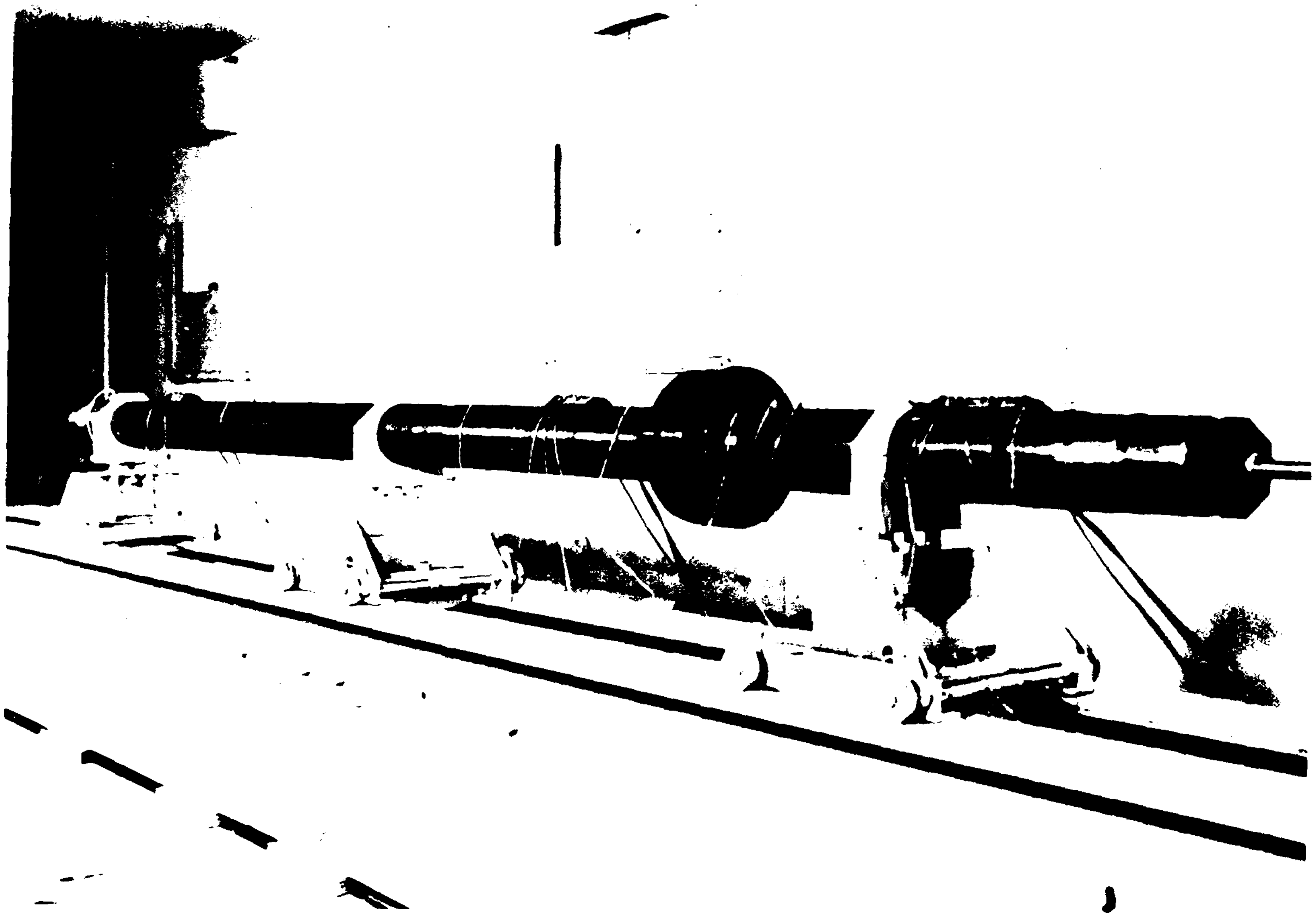


Figure 6. 40-mm Ballistic Tube Test Setup

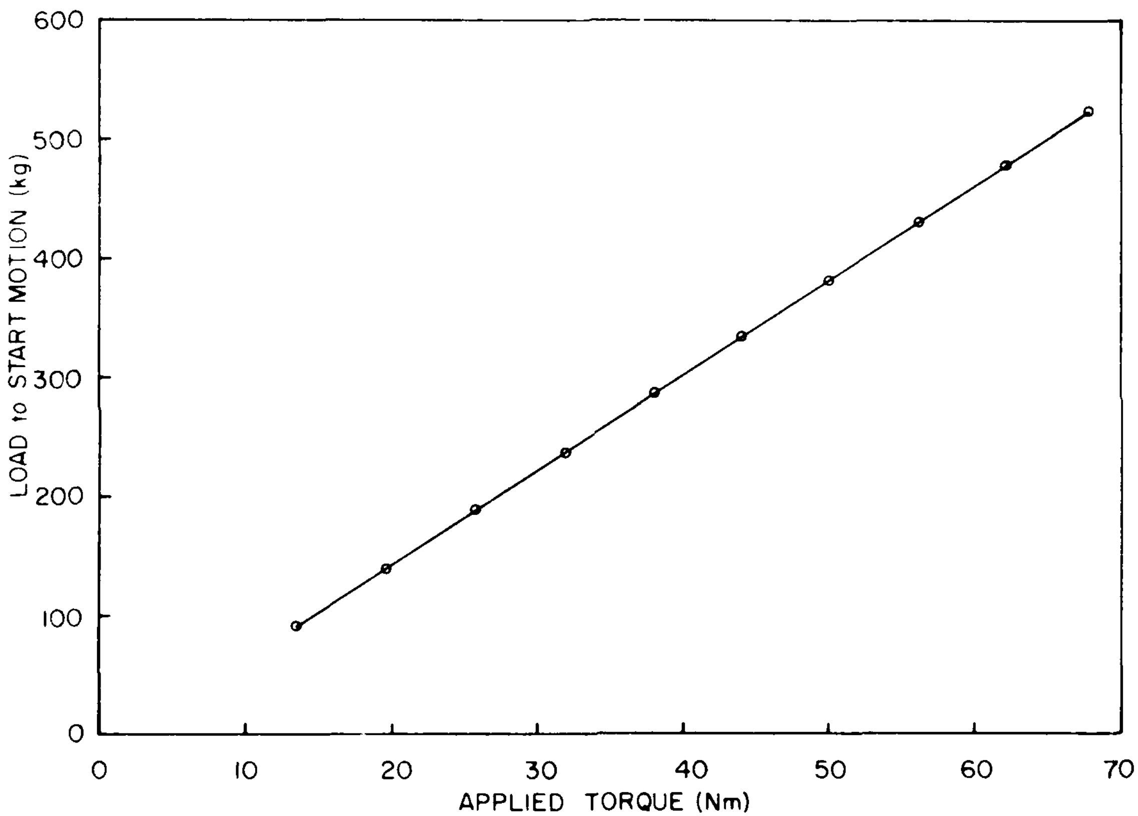


Figure 5. Load to Start Motion vs Torque Applied to Projectile

The torque bolt, part 5, is the base of the projectile and used as a guide for the alignment sleeve and is a screw for the alignment nut. The front end of the torque bolt is threaded for tightening the apparatus. The remainder of the shaft to the conical taper of the head is machined to a close tolerance for support of the alignment sleeve. The included conical angle is 90 degrees. This angle is larger than the mating angle of the rear band. Therefore, as the assembly is tightened, more band surface area is forced against the tube wall increasing the normal force. The rear face of the torque bolt has four small diameter holes 90 degrees apart at the same radial distance from the center-line of the bolt to accept a four-pronged socket used to tighten the apparatus.

IV. TEST SET-UP

A. Calibration

To obtain a calibration constant for applied torque vs shot-start pressure, a shot-start projectile was positioned in a section of a discarded 40-mm gun tube and was set to a specific torque setting. A rod was placed against the base of the projectile and a Baldwin testing machine was used to obtain the static load necessary to start motion. These data are plotted and presented in Figure 5. This test was conducted to check the linear relationships at specific torque levels. The low density polyethylene used as the band material tended to slowly conform to the void around the metal parts of the projectile, relieving the initial torque. After 60 seconds, the assembly was tightened further to bring the torque back up to the desired level. Apparently no significant flow took place after this, as subsequent tightening was unnecessary to maintain the desired torque.

B. Instrumentation

A 40-mm smoothbore gun tube, Figure 6, was used to measure the shot-start pressure. "Minihat" pressure transducers[2] were mounted in the gun tube at the breech end of the chamber and at the location where the base of the projectile was positioned prior to firing, is shown in Figure 7. A 10 GHz microwave interferometer was used to obtain the start of projectile movement and its travel throughout the length of the gun tube. The Ballistic Data Acquisition System (BALDAS) which is basically a PDP-11 computer system was used to automatically control the sequencing and operation for calibration, firing, initiating data retrieval, data conversion, and data storage.

V. RESULTS

Tests were conducted to correlate the shot-start pressure for selected amounts of torque applied to the projectile. Data were obtained for torque levels of 13.6 Nm, 38.9Nm, 47.5Nm, and 67.8Nm. Other intermediate levels were attempted; however, the data channels were noisy and of poor quality. Data from two of the rounds fired, numbered 54 and 56, are presented in plotted form as a function of time in Figures 8 through 11. The interferometer

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[2] T.L. Brosseau, "Development of the Minihat Pressure Transducer for Use in the Extreme Environments of Small Caliber Gun Barrels," BRL Memorandum Report No. ARBRL-MR-[illegible], Nov 197[illegible]. (AD [illegible])

FIG. 1

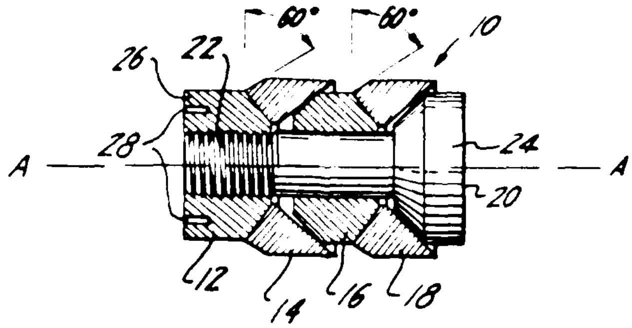


FIG. 2

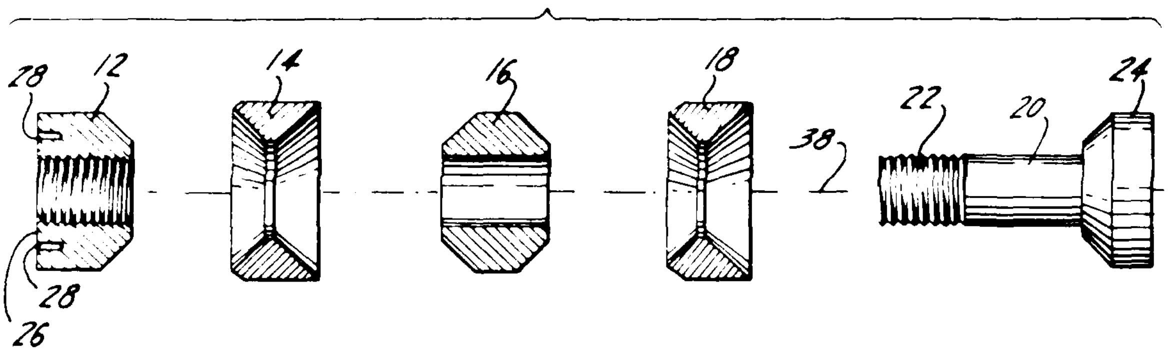


FIG. 3

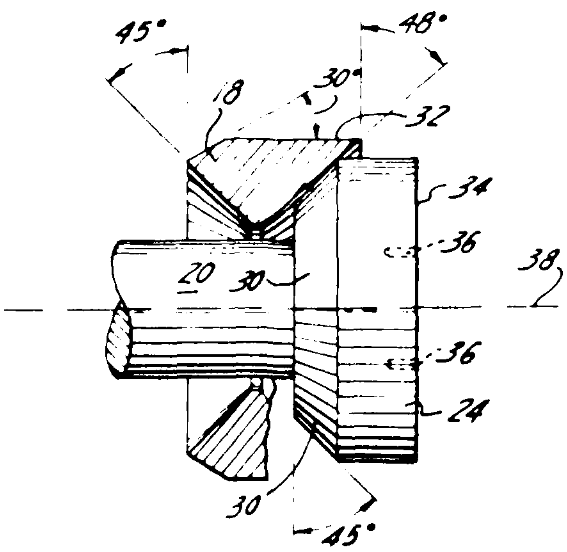
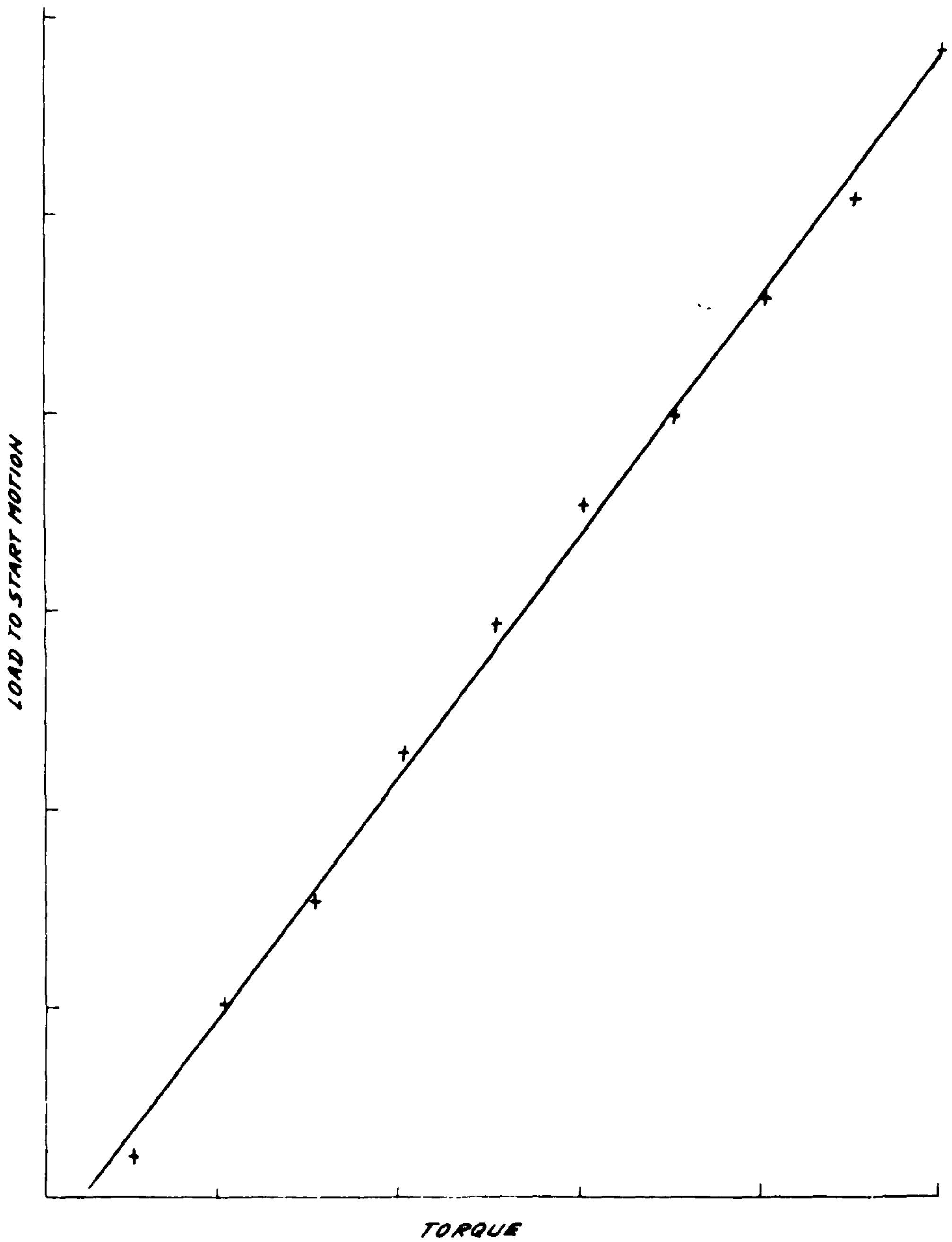


FIG. 4



LOAD TO START MOTION vs. TORQUE APPLIED TO PROJECTILE

FIG. 5

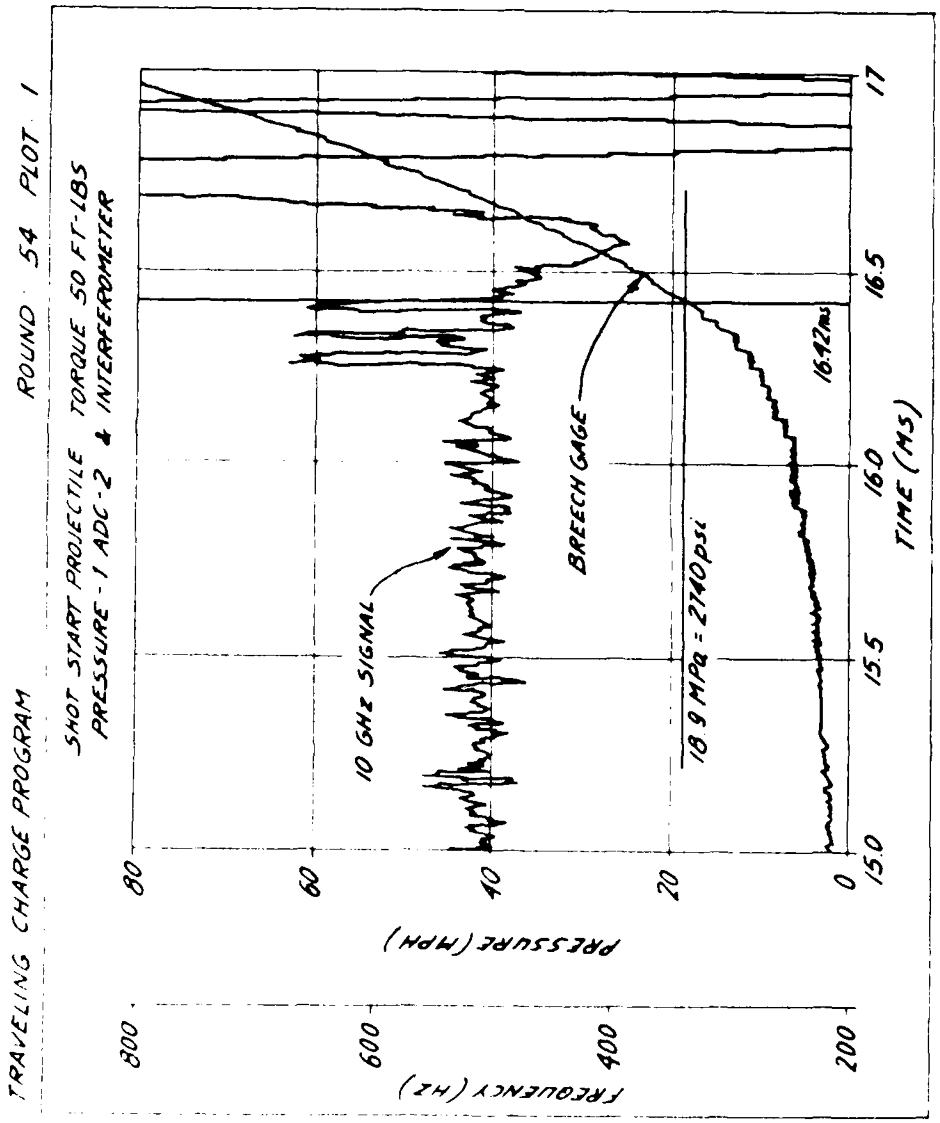

TRAVELING CHARGE PROGRAM
ROUND 54 PLOT 1
SHOT START PROJECTILE TORQUE 50 FT-LBS
PRESSURE-1 ADC-2 & INTERFEROMETER
10 GHz SIGNAL
BREECH GAGE
18.9 MPa = 2740 psi
16.42ms
80
60
40
20
0
PRESSURE (MPA)
800
600
400
200
FREQUENCY (HZ)
15.0
15.5
16.0
16.5
17
TIME (MS)

FIG. 6

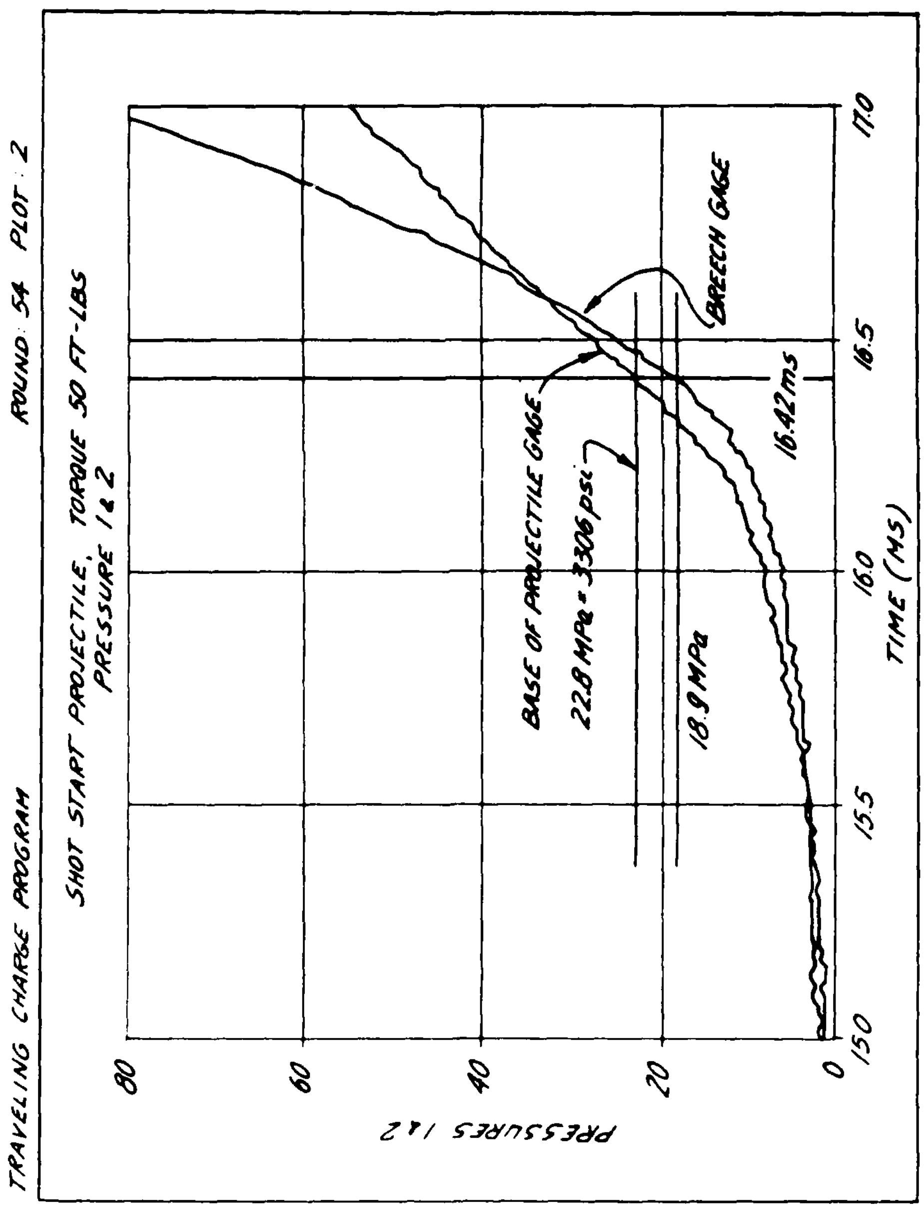

TRAVELING CHARGE PROGRAM
ROUND 54 PLOT 2
SHOT START PROJECTILE, TORQUE 50 FT-LBS
PRESSURE 1 & 2
BREECH GAGE
BASE OF PROJECTILE GAGE
22.8 MPa = 3306 psi
18.9 MPa
16.42 ms
80
60
40
20
0
15.0
15.5
16.0
16.5
17.0
TIME (MS)
PRESSURES 1 & 2

FIG. 7

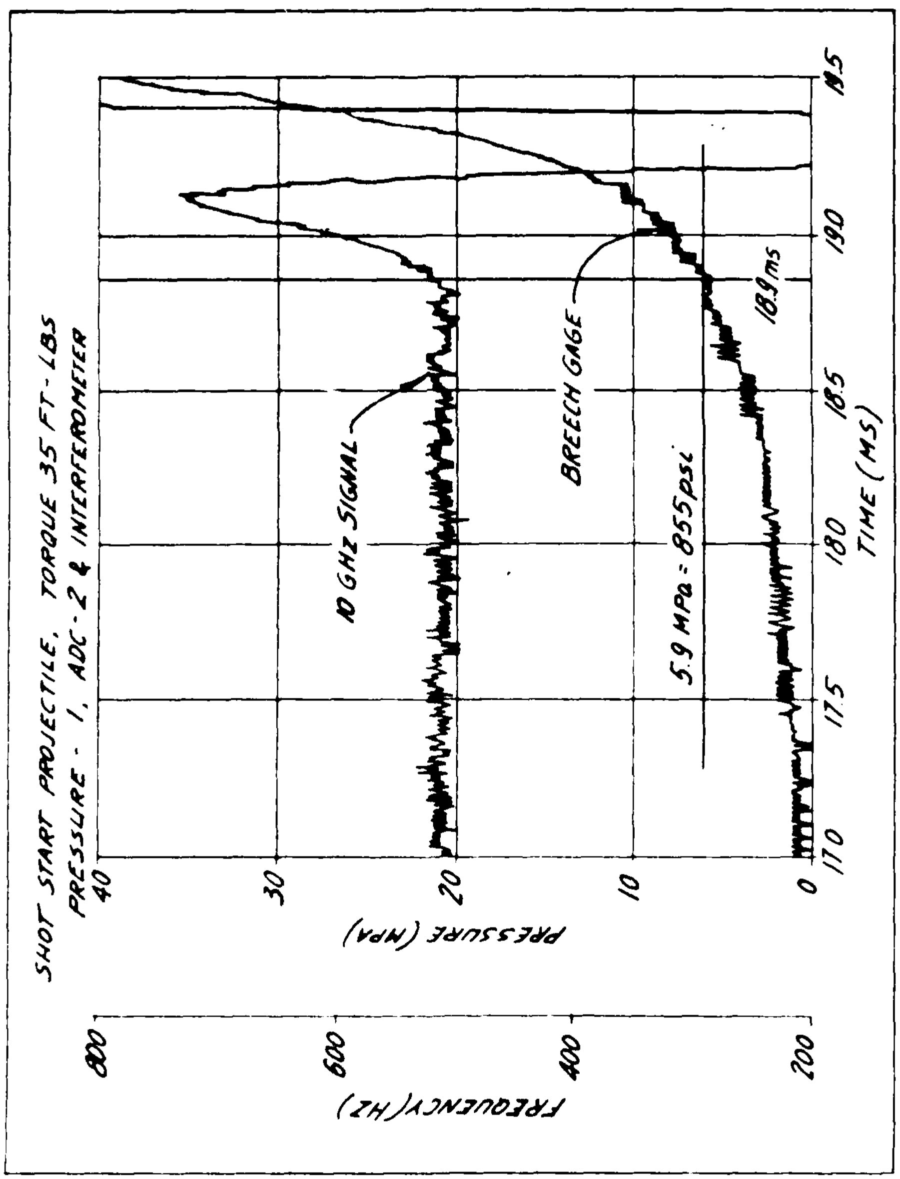
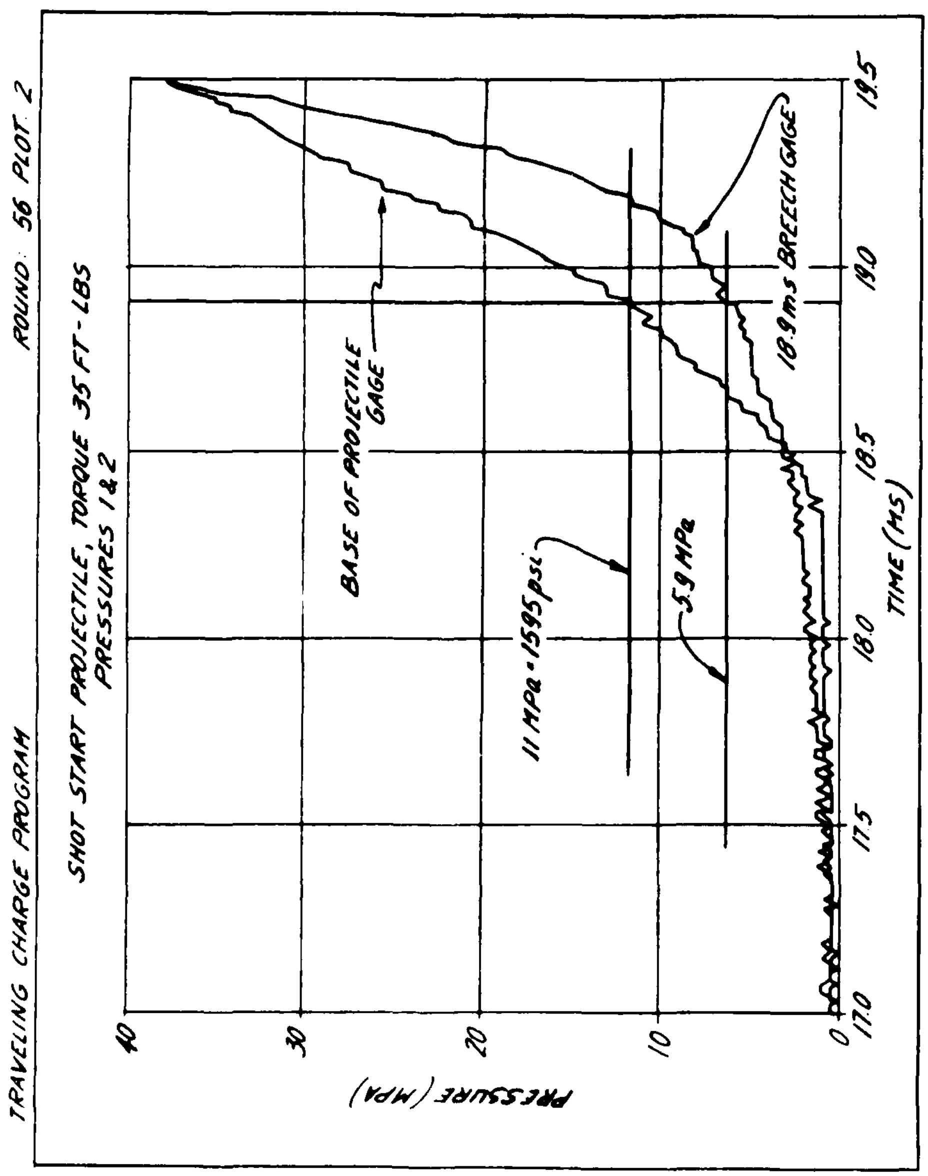

TRAVELING CHARGE PROGRAM
ROUND 56 PLOT 1
SHOT START PROJECTILE, TORQUE 35 FT-LBS
PRESSURE - 1, ADC - 2 & INTERFEROMETER
10 GHz SIGNAL
BREECH GAGE
5.9 MPa = 855 psi
18.9 ms
PRESSURE (MPA)
40
30
20
10
0
FREQUENCY (HZ)
800
600
400
200
TIME (MS)
170
175
180
185
190
195

FIG. 8


TRAVELING CHARGE PROGRAM
ROUND 56 PLOT 2
SHOT START PROJECTILE, TORQUE 35 FT-LBS
PRESSURES 1&2
BASE OF PROJECTILE GAGE
BREECH GAGE
18.9ms
11 MPa = 1595 psi
5.9 MPa
PRESSURE (MPA)
TIME (MS)
0
10
20
30
40
17.0
17.5
18.0
18.5
19.0
19.5

SHOT START PROJECTILE APPARATUS

GOVERNMENTAL INTEREST

The invention described herein may be manufactured, used and licensed by or for the Government for governmental purposes without the payment to me of any royalty thereon.

BACKGROUND OF THE INVENTION

The present invention relates to the field of art dealing with projectiles. More particularly, the present invention relates to an apparatus which can be secured in a new or worn gun tube to obtain improved ballistic results.

A worn gun tube produces many variations in interior and exterior ballistic performance and makes the determinations of performance parameters unreliable. Gun tubes erode from repeated firings by the movement of high temperature gases and residues generated from burning propellant, by chemical action and by friction between the projectile and bore. As the gun tube erodes, the initial pressure required to accelerate the projectile is reduced and hot gases escape around the projectile causing increased wear and a substantial reduction in projectile velocity and launch stability. In order to solve this problem, the following two methods are known in the prior art.

First method is to machine or mold a rotating band or obturator of larger diameter than the eroded cross section of the barrel at the critical seat position. This requires a slightly larger band or obturator for each firing or several made to the same oversize diameter. However, the first band would be difficult to position properly and the last would tend to be easy to position properly.

A second method is to rechamber the gun tube in a machine shop, thereby making the gun tube shorter or boring out the chamber to replace the removed material with a sleeve having the original chamber dimensions.

The basic shortcoming in prior art methods have related to an absence of improved ballistic results. Further, said methods are time consuming and produce additional problems to the ballistician and test personnel. This problem has, in the prior art, proven to be a formidable one. Accordingly, the present invention is intended as a solution to said problems.

SUMMARY OF THE INVENTION

The present invention discloses a shot-start projectile apparatus for a worn gun tube. The apparatus can be fitted to a projectile as an ancillary obturator or can be designed to the proper weight and used as the projectile. The apparatus comprises a torque bolt having a shaft threaded at one end and having a head at the opposite end thereof, a rear band having conical surfaces, said band being disposed on the shaft of the torgue bolt with an outside chamfer facing the threaded shaft when positioned against the torque bolt head, an alignment sleeve engaging the conical surfaces of the rear band, a front band symmetrical in shape with the rear band and the front band having engagements against the alignment sleeve, and an alignment nut having a conical surface facing the front end in which inside thread of the nut securely engages all of the components of the apparatus. The front and rear bands can be made from metallic or non-metallic material. The remaining components are made of metal. The alignment nut is

considered the front of the projectile. The front and rear bands provide obturation to prevent hot propellant gases from leaking in front of the projectile.

It is an object of the present invention to provide an apparatus that can be fitted to a projectile as an ancillary obturator or designed to the proper weight and used as the projectile.

It is a further object of the present invention to provide an apparatus which can be easily secured in a new or worn gun tube to obtain a desired initial pressure in the chamber that will insure proper ignition and burning of the propellant to achieve improved ballistic results.

It is a yet further object of the present invention to provide improved usefulness to a worn gun tube which is considered as unserviceable.

It is a still further object of the invention to reduce gun tube wear.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a partial cross-sectional view of a shot-start projectile apparatus, in an assembled form.

FIG. **2** is an exploded view of all the elements of the apparatus in unassembled form.

FIG. **3** is a partial breakway view taken along line A—A of FIG. **1** showing inside cross-sectional view, the angular relationship between the torque bolt and the rear band of the apparatus.

FIG. **4** is a graph of Load to Start Motion V. Torque Applied to Projectile.

FIG. **5** is a graph of Pressure V. Time, for round **54**.

FIG. **6** is a graph of Pressure V. Time for round **54** illustrating comparison of the output of the breech pressure gage and the base of projectile gage.

FIG. **7** is a graph of Pressure V. Time for round **56**.

FIG. **8** is a graph of Pressure V. Time for round **56** illustrating comparison of the output of the breech pressure gage and the base of projectile gage.

DETAILED DESCRIPTION OF THE INVENTION

As shown in FIG. **1**, a shot-start projectile apparatus **10** is illustrated as an assembled apparatus comprising an alignment nut **12**, a front band **14**, an alignment sleeve **16**, a rear band **18**, and a torque bolt **20**. The front and rear bands **14** and **18** are identical and they can be made from metallic or nonmetallic material. The alignment nut **12**, the alignment sleeve **16** and the torque bolt **20** are made of metal. The front end of the band has the outside diameter chamfered with an included angle of approximately 60 degrees. The torque bolt **14** comprises a threaded shaft **22** at one end and a head **24** at opposite ends of the shaft.

As shown in FIG. **2**, the rear band **18** is placed on the shaft of the torque bolt **20** with the outside chamfer facing the threads of the shaft when positioned against the torque bolt head. The alignment sleeve **16** is placed on the shaft of the torque bolt followed by the front band **14**. The front band **14** is placed on the shaft to be symmetrical with the rear band **18**. The alignment nut **12** is then threaded by hand on the torque bolt shaft, with the conical surface facing the front band **14**, until all the components of the apparatus **10** are finger-tight.

The apparatus **10** is inserted in the gun tube (not shown) to the projectile seat position. The torque bolt **20** is rotated clock-wise while holding the alignment nut **12** from rotating. This causes the conical surfaces, having an included angle of approximately 90 degrees, of the alignment nut **12**, alignment sleeve **16** and the torque bolt **20** to engage against the conical surfaces of the front and rear bands **14** and **18**. As the alignment nut **12** and the torque bolt **20** are tightened, the front conical angle of the alignment sleeve **16** and the torque bolt **20** engage more surface area of the rear included conical angle of approximately 84 degrees of the front and rear bands **14** and **18**. The torque applied to the torque bolt **20** determines the normal force N with which front and rear bands exert against the gun tube wall. The actual static force $F \geq \mu N$ where μ is the coefficient of static friction.

A charge, not shown, is placed into the weapon chamber and the breech closed. As ignition occurs, the pressure increases and with the flame spreading provides the proper media for good ignition and burning of the main charge. The pressure produced by the burning of the main charge overcomes the static friction force and the projectile is propelled down the gun tube by the rapidly increasing pressure. The front and rear bands **14** and **18** respectively provide obturation to prevent hot propellant gases from leaking in front of the projectile.

The alignment nut **12** has a flat end **26** which contains four small diameter holes **28** which are 90 degrees apart and are the same radial distance from the center line of the nut to accept a four pronged socket used to tighten the apparatus **10**. The opposite end has an included conical angle of approximately 90 degrees used to align the front band **14** and force the band radially against the gun tube wall, not shown.

The front band **14** is a band/obturator. The position of the 60 degree included chamfer on the outside diameter is the front. The internal front conical angle of 90 degrees mates with the conical angle of the alignment nut **12**. The internal rear conical angle of approximately 84 degrees does not mate with the conical angle of the alignment sleeve **16**. Therefore, as the assembly is tightened more band surface area is forced against the tube wall increasing the normal force.

The alignment sleeve **16** is a symmetrical spacer used to transmit equal force against both the front and rear bands as the assembly is tightened. The included angles of both ends are approximately 90 degrees.

The rear band **18** is identical to the front band **14** and is positioned with the outside chamfer angle facing the alignment nut **12**. The internal front conical angle is the same as the conical angle of the alignment sleeve. The internal rear conical angle of approximately 84 degrees does not mate with the conical angle of the torque bolt. Therefore, as the assembly is tightened more band surface area is forced against the tube wall increasing the normal force.

As shown in FIG. **3**, the conical taper **30** of the head **24** is machined to a close tolerance for support of the alignment sleeve. The included conical angle is 90 degrees. This angle is larger than the mating angle of the rear band **18**. Therefore, as the assembly is tightened more band surface area **32** is forced against the tube wall increasing the normal force. The rear face **34** of the torque bolt has four small diameter holes **36** which are positioned 90 degrees apart and are the same radial distance from the center line **38** of the bolt **20** to accept a four pronged socket, not shown, which may be used to tighten the apparatus **10**.

The outside diameter of the bands **14** and **18** are slightly larger than the diameters of the other three parts **12**, **16** and **24** of the apparatus **10**.

The shot-start projectile apparatus **10** has been designed, fabricated, calibrated and successfully tested. The alignment nut **12**, alignment sleeve **16** and torque bolt **20** have been fabricated from aluminum and the front band **14** and rear band **18** have been fabricated from such material as polyethelene. The shot-start projectile was positioned in a section of discarded mm gun tubes at specific torque settings. A rod was placed against the base of the projectile and a Baldwin testing machine was used to obtain the static load necessary to start motion. This data is plotted and presented in FIG. **4**. A 40 mm smooth bore gun tube has been used to measure the shot-shart pressure. "Minihat" pressure transducers are mounted in the gun tube at the breech end of the chamber and at the position where the base of the projectile is prior to firing. A 10 GHz microwave interferometer was used to obtain the start of projectile movement and its travel throughout the length of the gun tube. Data from two of the rounds fired, **54** and **56**, are presented in plotted form in FIGS. **5** through **8**. The interferometer and breech pressure V. time of each round are presented in FIGS. **5** and **7**. The output of the breech pressure gage and the gage where the base of the projectile is positioned V time for each round are plotted in FIGS. **6** and **8**. The measured pressure at the base of the projectile at start of projectile motion for round **54** is 22.8 MPa (3306 psi) and for round **56** is 11 MPa (1595 psi).

As shown in FIG. 7, when the 10 GHz signal deviates from its baseline, motion of the projectile has started. A vertical line was drawn at this point to intersect the breech gage output to determine the breech at this point in time. A vertical line is drawn on FIG. **8** at the same point in the time scale. Where this line crosses the output signal of the gage positioned at the base of the projectile determines the shot-start pressure. The breech gage is also plotted as a position check.

Accordingly, while there have been shown and described the preferred embodiments of the present invention, it will be understood that the invention may be embodied otherwise than as herein specifically illustrated or described and that within said embodiments certain changes in the detail and construction, and the form of arrangement of the parts may be made without departing from the underlying idea or principles of this invention within the scope of the appended claims.

I claim:

1. A shot-start projectile apparatus for a worn gun tube, which comprises:

(a) a torque bolt having a shaft, said shaft being threaded at one end and having a head at the opposite end thereof which includes a conical taper thereon;

(b) a rear band having a plurality of unequally angled conical surfaces, said rear band having an outside chamfer thereon, said outside chamfer facing the threaded shaft when one of the conical surfaces of the rear band is positioned on the shaft against the conical taper of said torque bolt head;

(c) an alignment sleeve having conical surfaces on each end thereof, one end engaging one of the other conical surfaces of the rear band;

(d) a front band having a plurality of unequally angled conical surfaces, said band being symmetrical in shape to said rear band, said rear band and said front band having conical surface engagements against said alignment sleeve, and

(e) an alignment nut having a conical surface facing said front band, in which inside thread of said nut securely engages the threaded shaft of said torque bolt.

2. The shot-start projectile apparatus as recited in claim 1 in which said torque bolt shaft, upon tightening comprises means for producing a normal force between the inside surface of the gun tube and both of said bands in order to restrain projectile motion until a desired pressure is reached in said gun tube.

3. The shot-start projectile apparatus as recited in claim 1 in which the front and rear bands comprises means for providing obturation for prevention of hot propellant gases from leaking in front of the projectile, and means for axially aligning said projectile in said gun tube.

4. The shot-start projectile apparatus as recited in claim 1, in which a rear face of said torque bolt comprises a plurality of grooves in which a pronged socket is received to tighten said projectile.

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